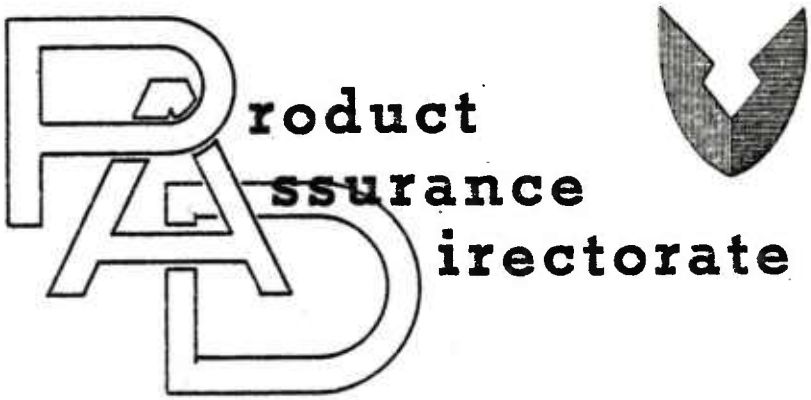
WVT-QA-8302

Gun Tube Forging Straightness Measurement System

Richard Campolmi

February 1983



Watervliet Arsenal
Watervliet, New York
12189

Technical Report

AMCMS No. 5397.OM.6350
Pron No. A1-0-P6353-04-AW-M7

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: WVT-QA-8302	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE *(and Subtitle)*: Gun Tube Forging Straightness Measurement System	5. TYPE OF REPORT & PERIOD COVERED: Final Technical Jul 80 - Sep 82
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Richard Campolmi	8. CONTRACT OR GRANT NUMBER(s): AMCMS #5397.0M.6350
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Watervliet Arsenal, Product Assurance Directorate, SARWV-QAE, Watervliet, N.Y. 12189	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: A1-0-P6353-04-AW-M7
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Armament Materiel Readiness Command, DRSAR-QAE, Rock Island, IL 61299	12. REPORT DATE: Feb 1983
	13. NUMBER OF PAGES: 16
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*: Army Materials and Mechanics Research Center, AMXMR-MQ, Watertown, MA 02172	15. SECURITY CLASS. *(of this report)*: Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release: Distribution Unlimited

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Straightness Measurements
Gun Tube Forgings
Runout
Computers

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

An MTT project was funded to automate OD runout measurements on gun tube forgings from which straightness data is generated. ID straightness measurements proved more useful. A spec was prepared and fifteen firms solicited. The sole bid was three times original estimate which lead to the cancellation of the project.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

MATERIALS TESTING TECHNOLOGY PROGRAM (AMS 4931)

Report No. WVT-QA-8302 Title: Gun Tube Forging Straightness Measurement System

THIS PROJECT HAS BEEN ACCOMPLISHED AS PART OF THE US ARMY MATERIALS TESTING TECHNOLOGY PROGRAM, WHICH HAS FOR ITS OBJECTIVE THE TIMELY ESTABLISHMENT OF TESTING TECHNIQUES, PROCEDURES OR PROTOTYPE EQUIPMENT (IN MECHANICAL, CHEMICAL, OR NONDESTRUCTIVE TESTING) FOR MATERIEL/MATERIAL PROCURED OR MAINTAINED BY AMC.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

APPENDICES

1. INTRODUCTION

The manufacture of modern, high pressure cannon tubes is a multi-step process requiring precision machining of both the internal and external features. Typical manufacturing tolerances are on the order of a few mils and can extend over the full length of the tube. Concurrent with the size requirement is an equally demanding straightness requirement. The latter is driven by the need for high accuracy and the desire to reduce machining time and forging weight i.e., limiting the amount of material removed during subsequent machining operations.

Several methods of measuring bore straightness have been developed over the years [1]. One of these which is still in use involves the use of an optical target which is drawn through the tube by means of a knotted cord. Axial misalignment is read from an alignment telescope which is aimed at the target. An X-Y chart for the various degrees of misalignment eliminates the need for an inspector to perform vector calculations and enables him to quickly spot any out of tolerance condititions. A more recent development is the use of a laser and an electronic target mounted on a head which is traversed through the bore. Under computer control, straightness measurements are made at predetermined locations in the tube bore, the computations are performed on the data and an inspection report is generated. The operator is only required to load the tube into the station, type in the tube shop number and initiate the inspection cycle.

[1]A.H. Rybaltowski and F.J. Audino, "Investigation of Advanced Methods of Measuring Cannon Tube Bend", Watervliet Arsenal Technicial Report, WVT-QA-6901, 1969

2.FORGING APPLICATIONS

Both of the foregoing methods are used on machined gun tubes. Tube forgings, however, which may have bows exceeding one inch require a different approach. Additional difficulties are created by bore surface conditions such as rust, scale and diameter variations as much as 1/8 inch. Cold straightening limits require that the tube forgings be screened prior to routing to the straightening presses so as to avoid a tie up of valuable operator/machine time. Therefore, wall variation and straightness measurements are taken from the tube forgings before they enter the manufacturing line.

Forging straightness measurements are not made directly but are inferred from runout measurements made either using a dial indicator on the outside diameter of the tube (see Fig. 1) or by passing a trolley through the bore of the tube. The trolley electromagnetically senses the bore surface standoff and is coupled via a pair of wires to an analog meter (Shown in the upper left of Fig. 2) where the runout is read as the variation in the deflection of the needle. Obviously, neither of these methods are as accurate as the methods used on finish machined tubes, but are sufficiently accurate (To approximately .10") to serve the purpose.

3. ORIGINAL CONCEPT

The original project concept was to automate the dial indicator/OD runout measurement technique. This could be accomplished by mounting a series of extended range transducers on the machine as shown in Figure 3. These transducers would be connected to individual amplifiers which would be

interfaced to a minicomputer. A single rotation of the tube would be required to generate a high and a low reading from each transducer. The minicomputer could then assimilate the data, perform the calculations and output the inspection report in the desired format. An alternative method would use a single transducer mounted on a carriage driven by a lead screw. While possibly less costly, inspection time would be increased since it would be necessary for the carriage to traverse to each inspection location stopping each time to rotate the tube forging in order to generate the required runout data.

4. ID STRAIGHTNESS MEASUREMENTS

The previously mentioned difficulies of detecting large bows in tube forgings and the problems created by bore surface conditions have hindered the application of ID straightness techniques used on machined gun tubes to tube forgings. Although it is more expedient to measure OD runout, ID straightness data is more pertinent to subsequent machining operations such as guided boring. The reason being that the bore guidance machine, which bores the forging in one pass, can tolerate axial misalignments up to 1/4 inch. After discussions with Product Engineering and Quality Control, it was decided to change the project scope of work from the application of an automated OD runout measurement system to a direct ID measurement technique.

A specification was prepared (see Appendix A) and submitted to Procurement. A request for technical proposals was sent to fifeteen firms (see Appendix B). Only one firm responded. Under step 2 of the solicitation this firm submitted a bid of $249,248. Since this was almost

three times the estimate, it was decided to cancel the solicitation. The original project savings were not large enough to justify the increased equipment cost and it was therefore concluded that the project should be terminated and the funds returned to AMMRC.

5. CONCLUSIONS

The need for an automated method to measure forging straightness still exists. Straightening of gun tubes which is done on a hydraulic press occurs a minimum of three times during the manufacturing process. An average of three hours is allowed for each pressing operation. An improvement in the efficiency of this operation would yield significant savings.

Several problems must be overcome before this can become a reality: one, the measurement system must be suitable for installation on the press; two, the information must be presented in a format that is understandable to the operator; three, the equipment must be capable of reliable operation in a harsh industrial environment; and fourth, the equipment cannot interfere with the safety cable which is strung through the center of the bore during the pressing operation. The pressing operation is an iterative process of pressing, measuring, pressing, etc. until the operator has straightened the tube to within the required limits. If it were necessary to remove the cable for each measurement the time required for pressing would be lengthened considerably.

6. RECOMMENDATIONS

The next step, after the development of an automated measurement system, would be the automation of the entire straightening process. New stroke controlled presses are being purchased which would facilitate this effort. Hardware for the interface should not require significant development. Software, on the other hand, will require extensive development in order to effectively replace the current manual procedure which is totally dependant on operator judgement for the placement of the tube, the supports and the ram as well as the deflection applied. Considerable training and experience is required before an operator becomes qualified. Today's emphasis on improvements in quality and productivity suggest that the feasibility of this project be investigated.

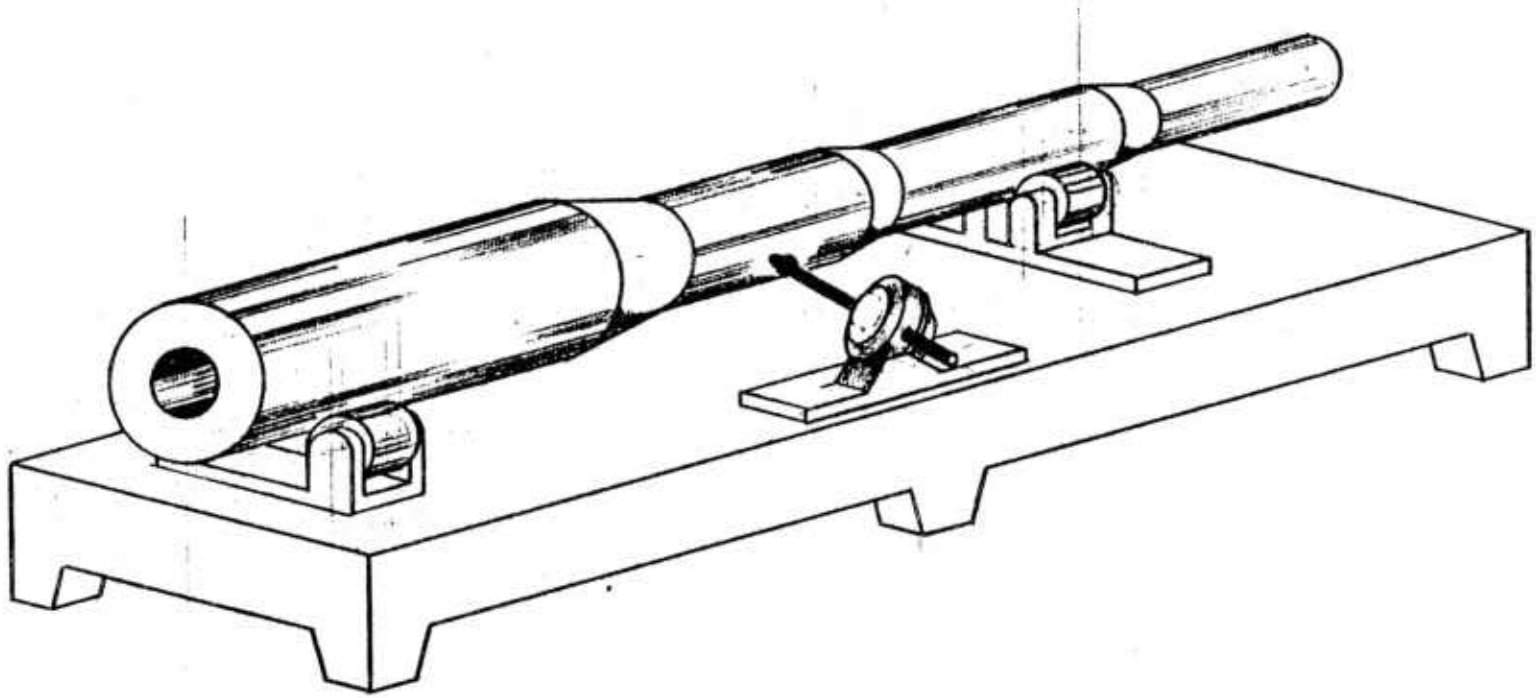


FIGURE 1. O.D. "TIR" MEASUREMENT

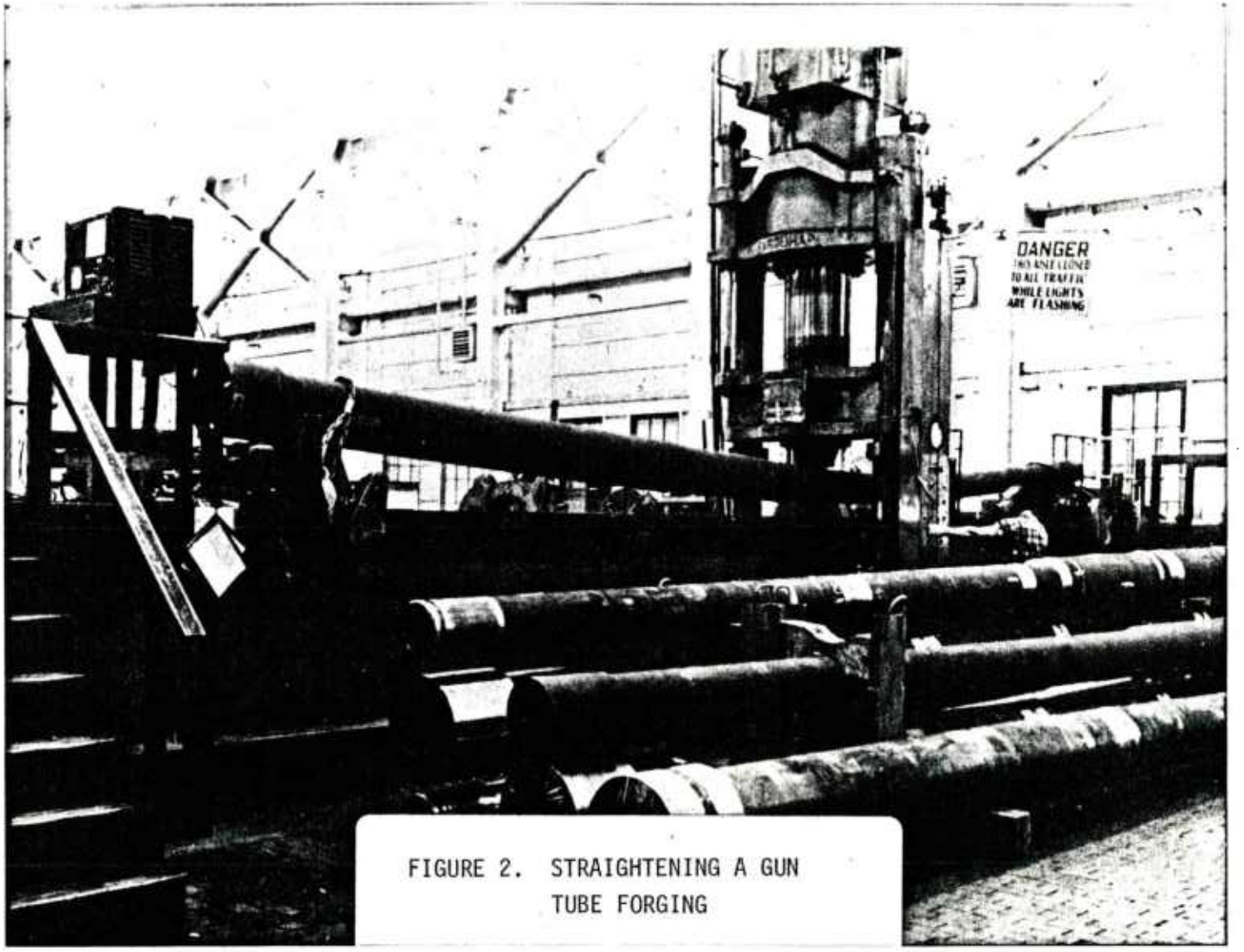


FIGURE 2. STRAIGHTENING A GUN TUBE FORGING

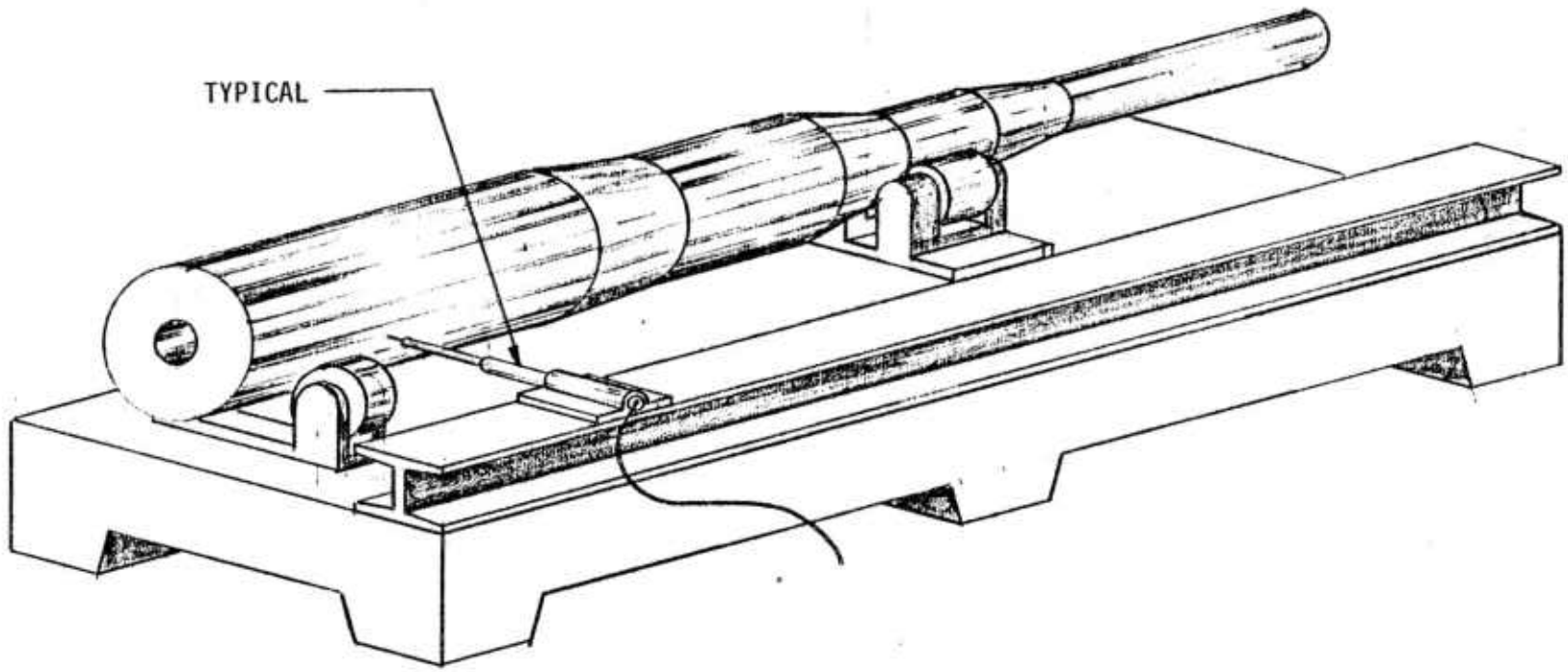


FIGURE 3. O.D. MEASUREMENT TRANSDUCER

Appendix A

GUN TUBE FORGING STRAIGHTNESS INSPECTION SYSTEM

1. SCOPE

1.1 CONTENTS: THIS DOCUMENT CONTAINS THE REQUIREMENTS FOR A GUN TUBE FORGING INSPECTION SYSTEM.

1.2 DESCRIPTION: THE INSPECTION SYSTEM COVERED BY THIS SPECIFICATION SHALL BE CAPABLE OF PROVIDING THE FOLLOWING PHYSICAL DIMENSIONS OF A GUN TUBE FORGING:

a. VERTICLE AND HORIZONTAL DISPLACEMENT OF THE FORGING ID CENTERLINE FROM THE ID CENTERLINE ESTABLISHED BETWEEN THE ENDS OF THE FORGING.

b. THE LONGITUDINAL DISTANCE OF THIS DEVIATION FROM THE BREECH END OF THE FORGING.

THIS INFORMATION SHALL BE PROVIDED VIA DIGITAL READOUT AND PRINTED INSPECTION REPORT.

THIS SYSTEM SHALL BE USED ON THE FOLLOWING GUN TUBE FORGINGS: 105MM M68, DWG 11579641; 120MM M256, DWG 12529796; AND 155MM M185, DWG 11579504.

2. APPLICABLE STANDARDS AND PUBLICATIONS: VARIOUS STANDARDS AND OTHER PUBLICATIONS ARE REFERENCED OR REQUIRED IN THIS SPECIFICATION. WHERE THEY ARE REFERENCED OR REQUIRED, THEY ARE MEANT TO INDICATE AN ACCEPTABLE LEVEL OF QUALITY, SAFETY OR PERFORMANCE. EXCEPT WHERE IT IS INDICATED IN THIS SPECIFICATION THAT NO SUBSTITUTIONS ARE PERMITTED, OFFERORS MAY CHOOSE TO ADHERE TO STANDARDS OTHER THAN THOSE SPECIFIED, PROVIDED THAT THE SUBSTITUTE REPRESENTS A LEVEL OF QUALITY, SAFETY OR PERFORMANCE EQUAL TO OR BETTER THAN THE ONE SPECIFIED. ANY SUBSTITUTIONS MUST BE CLEARLY DISCLOSED AND EXPLAINED IN THE OFFEROR'S STATEMENT OF COMPLIANCE (See 6.2). ANY STANDARDS ADHERED TO IN COMPLYING WITH THIS SPECIFICATION SHALL BE THE LATEST ISSUES IN EFFECT ON THE DATE OF SOLICITATION OF OFFERS AND OFFERORS ARE RESPONSIBLE FOR OBTAINING COPIES OF THE MOST CURRENT REVISIONS.

3. REQUIREMENTS

3.1 GENERAL REQUIREMENTS:

3.1.1 DESIGN & ENGINEERING. THE SYSTEM SHALL BE DESIGNED AND ENGINEERED IN ACCORDANCE WITH CURRENT STANDARDS RECOGNIZED OR ADOPTED BY THE NATIONAL MACHINE TOOL BUILDERS ASSOCATION. THE DESIGN AND ENGINEERING SHALL BE OF THE LATEST TYPE BUT SHALL INCORPORATE ONLY CONCEPTS, SYSTEMS AND COMPONENTS WHICH HAVE BEEN PROVED IN PRIOR USE.

MODIFICATIONS TO MANUFACTURERS' STANDARD DESIGNS TO ACHIEVE REQUIREMENTS SPECIFIED HEREIN ARE NOT PERMISSIBLE IF THEY RESULT IN DEVIATIONS FROM GOOD DESIGN PRACTICE. EXAMPLES OF SUCH IMPERMISSIBLE MODIFICATIONS ARE PLACING A 20HP MOTOR IN A POWER TRAIN DESIGNED FOR 10HP, OR RAISING THE HEADSTOCK ON A 25-INCH LATHE BED TO ACHIEVE A 32-INCH SWING.

3.1.2 MATERIALS. MATERIALS INCORPORATED IN THE CONSTRUCTION OF THE GAGE SHALL BE OF SOUND AND UNIFORM QUALITY, FREE FROM DEFECTS AND SHALL CONFORM IN SPECIFICATION, HEAT TREATMENT AND SUITABILITY TO THE STANDARDS RECOGNIZED OR ADOPTED BY THE NATIONAL MACHINE TOOL BUILDERS ASSOCIATION FOR THIS TYPE AND CLASS OF EQUIPMENT.

3.1.3 CONSTRUCTION. ALL PARTS OF THE GAGING SYSTEM BE NEW AND UNUSED AND SHALL BE CONSTRUCTED AS TO BE CAPABLE OF WITHSTANDING ALL FORCES ENCOUNTERED DURING ROUTINE USE.

3.1.4 WORKMANSHIP. WORKMANSHIP THROUGHOUT THE GAGING SYSTEM AND ITS EQUIPMENT SHALL BE EQUAL TO OR EXCEED THE STANDARDS RECOGNIZED BY THE NATIONAL MACHINE TOOL BUILDERS ASSOCIATION FOR THE TYPE, CLASS AND SIZE OF THE EQUIPMENT.

3.1.5 MAINTAINABILITY. ALL PARTS SUBJECT TO WEAR, DISTORTION OR FAILURE AND ALL PARTS WHICH REQUIRE PERIODIC ADJUSTMENT SHALL BE READILY AND SAFELY ACCESSIBLE FOR REPAIR, REPLACEMENT OR ADJUSTMENT AS APPLICABLE. INSTRUCTIONS FOR MAINTENANCE SHALL BE CLEAR, CONCISE, AND DEFINITE IN APPLICATION.

3.1.6 INTERCHANGEABILITY. ALL PARTS BEARING THE SAME PART NUMBER SHALL BE FUNCTIONALLY INTERCHANGEABLE.

3.1.7 LOCATION OF OPERATOR'S CONTROLS. THE OPERATOR'S CONTROLS FOR THE SIGNAL CONDITIONERS SHALL BE LOCATED INSUCH A MANNER THAT THEY ARE READILY ACCESSIBLE TO THE OPERATOR FROM THE POSITION WHERE HE WILL BE APPLYING THE GAGE IN THE TUBE.

3.1.8 GENERAL ELECTRICAL CHARACTERISTICS. THE ELECTRICAL SYSTEM SHALL CONFORM TO JIC (JOINT INDUSTRIAL COUNCIL) ELECTRICAL STANDARDS FOR GENERAL PURPOSE MACHINE TOOLS.

3.1.8.1 APPLICABLE POWER SOURCE. THE POWER SOURCE TO WHICH THE EQUIPMENT WILL BE CONNECTED FURNISHED 120 VOLT, SINGLE PHASE, 60 HZ AC, AND THE SYSTEM SHALL BE WIRED AND EQUIPPED ACCORDINGLY. IN ADDITION, THE SYSTEM SHALL BE TOLERANT ENOUGH OF LINE FLUCTURATIONS TO OPERATE NORMALLY AT SOURCE VOLTAGES RANGING FROM 108 TO 132.

3.1.8.2 CONVERSION EQUIPMENT. IF DC OR REDUCED VOLTAGE AC IS REQUIRED OR SPECIFIED FOR ANY PART OF THE SYSTEM'S OPERATION, THE NECESSARY CONVERSION OR TRANSFORMATION EQUIPMENT SHALL BE FURNISHED WITH THE SYSTEM.

3.1.8.3 OPERATOR CONTROL VOLTAGE. ALL CONTROLS NORMALLY ACTUATED BY THE OPERATOR OF THE EQUIPMENT SHALL OPERATE ON 120 VOLTS OR LESS.

3.1.9 SAFETY FEATURES. PROTECTION OF THE MACHINE OPERATOR AND OTHER PERSONNEL SHALL BE ACCOMPLISHED IN ACCORDANCE WITH TITLE 29, CODE OF FEDERAL REGULATIONS, PART 1910 - - THE APPLICATION SUBPARTS THEREOF AND THE CURRENT AMENDMENTS THERETO, EXCEPT AS OTHERWISE NOTED.

3.1.10 IDENTIFICATION PLATE. A CORROSION RESISTANT METAL PLATE SHALL BE SECURELY ATTACHED TO THE EQUIPMENT IN A VISIBLE LOCATION IN THE VICINITY OF

THE OPERATOR'S WORK STATION. THIS PLATE SHALL BEAR THE INFORMATION CALLED FOR AS FOLLOWS, WITH SPACE AT THE BOTTOM FOR ONE ADDITIONAL LINE OF INFORMATION.

NOMENCLATURE
MANUFACTURER'S NAME
MANUFACTURER'S MODEL NO.
MANUFACTURER'S SERIAL NO.
POWER INPUT (VOLTAGE, PHASE, FREQUENCY, TOTAL AMPS)
CONTRACT NO.
DATE OF MANUFACTURE

3.1.11 EXTERIOR SURFACES. ALL EXTERIOR SURFACES OF THE GAGE SHALL BE COATED WITH A SUITABLE PROTECTIVE FINISH EXCEPT WHERE BRIGHT METAL IS REQUIRED FOR THE GAGE FUNCTION OR TO OTHERWISE ADHERE TO THE REQUIREMENTS OF THIS SPECIFICATION. SHOULD THESE SURFACES BE ALUMINUM, ANODIZING WILL BE ACCEPTABLE, OTHERWISE PAINT SHALL BE REQUIRED. PAINT SHALL BE APPLIED IN SUCH A MANNER AND SHALL BE OF PROPER QUALITY TO AFFORD PROTECTION THROUGHOUT THE NORMAL LIFE OF THE GAGE. DANGEROUS AND CAUTION AREAS SHALL BE PAINTED YELLOW IN ACCORDANCE WITH OSHA, 1910, 144.

3.1.12 REPAIR/REPLACEMENT PARTS AVAILABILITY. THE SUPPLIER OF THE EQUIPMENT SHALL GUARANTEE THE AVAILABILITY OF PROPRIETARY REPAIR/REPLACEMENT PARTS FOR A PERIOD OF NOT LESS THAN 10 YEARS FOLLOWING DATE OF GAGE DELIVERY.

3.1.13 PNEUMATIC REQUIREMENTS. IF AIR IS REQUIRED FOR ANY GAGE OPERATION OR FUNCTION, A SUITABLE DRYER AND FILTER SHALL BE SUPPLIED. AVAILABLE HIGH PRESSURE AIR SUPPLY IS 80 PSI.

IF ANY GAGE FUNCTION REQUIRES AIR SUPPLY IN EXCESS OF 80 PSI, THE EQUIPMENT NEEDED TO SUPPLY THE HIGHER PRESSURE SHALL BE SUPPLIED WITH THE EQUIPMENT.

3.2 DETAILED DESIGN REQUIREMENTS. THE INSPECTION SYSTEM SHALL CONSIST ESSENTIALLY OF: THE SUPPORT SYSTEM WITH POWER ROLLERS, THE MEASURING SYSTEM WITH ASSOCIATED DRIVE/INDEXING SYSTEM, THE CALCULATOR/CONTROL SYSTEM, THE LASER, DISPLAYS, ALL REQUIRED INTERFACES AND CABINET ENCLOSURE AS DETAILED BELOW.

3.2.1 GUN TUBE SUPPORT SYSTEM.

3.2.1.1 THE SUPPORT SYSTEM SHALL CONSIST OF TWO SETS OF ROLLER SUPPORTS AND A SUITABLE STRUCTURE TO SUPPORT THE TUBE AT A HEIGHT OF BETWEEN 36 AND 48 INCHES ABOVE THE FLOOR. THE MAXIMUM FLOOR SPACE IS 45 FT X 12 FT. THIS SYSTEM SHALL BE CAPABLE OF SUPPORTING THE FOLLOWING GUN TUBE FORGINGS: 105MM M68, DWG 11579641; 120MM M256, DWG 12529796; 155MM M185, DWG 11579504.

3.2.1.2 ONE SET OF ROLLER SUPPORTS SHALL BE POWER DRIVEN AND CAPABLE OF ROTATING THE TUBE IN BOTH DIRECTIONS AT VARIABLE SPEED AND SHALL HAVE "JOG" PROVISIONS. ALL ROLLERS SHALL HAVE A RUBBER CONTACT SURFACE AND MUST NOT BE PERMANENTLY DEFORMED BY THE TUBE WEIGHT. ONE SET OF ROLLERS SHALL BE EQUIPPED WITH A LOCKING DEVICE, CAPABLE OF PREVENTING THE TUBE FROM ROTATING DURING INSPECTION.

3.2.1.3 TO FACILITATE THE ACCOMMODATION OF DIFFERENT GUN TUBE DIAMETERS, THE ROLLER SPACING SHALL BE ADJUSTABLE BY MEANS OF A LEAD SCREW SO THAT LEVELING, AND CENTERING OF THE TUBE WITH THE MEASURING HEAD INDEXING SYSTEM CAN BE ACCOMPLISHED QUICKLY AND ACCURATELY. BOTH ROLLER SUPPORT ASSEMBLIES SHALL BE CAPABLE OF INDEPENDENT LONGITUDIANL MOVEMENT AND SHALL BE EQUIPPED WITH A POSITIVE LOCKING DEVICE. A STOP SHALL BE USED TO POSITION THE TUBE AND SHALL BE MOUNTED SO IT CONTACTS THE TUBE FACE.

3.2.2 MEASURING SYSTEM. THE MEASURING SYSTEM SHALL MEASURE THE DEVIATION OF THE GUN TUBE FORGING FROM A THEORETICAL CENTERLINE ESTABLISHED BETWEEN EACH END OF THE TUBE. IN ALL CASES THE FEATURE USED TO ESTABLISH THE CENTERLINE SHALL BE THE INSIDE DIAMETER. AN ALIGNMENT LASER SYSTEM WITH A HEAD (WHICH PASSES THROUGH THE BORE), DETECTORS, AND AMPLIFIERS, SHALL BE USED TO MEASURE AND DISPLAY THE FOLLOWING DIMENSIONS: THE X AND Y COORDINATES, AND THE LONGITUDINAL DISTANCE FROM THE BREECH END OF THE TUBE. ALL DISPLAYS SHALL HAVE INCH/METRIC (MM) CAPABILITY.

3.2.3 INDEXING SYSTEM.

3.2.3.1 THE HEAD INDEXING SYSTEM SHALL BE CAPABLE OF DRIVING THE HEAD THROUGH THE ENTIRE GUN TUBE BORE IN BOTH DIRECTIONS WITHOUT DAMAGE TO THE BORE. THE DRIVING DEVICE SHALL BE EQUIPPED WITH A SLIP CLUTCH SO IT WILL STOP WITHOUT CAUSING DAMAGE TO THE TUBE OR THE MACHINE IF THE HEAD MEETS AN OBSTACLE. TOTAL MEASURING RANGE SHALL BE 28 FT MINIMUM. CONTROLS SHALL CONSIST OF: A SWITCH FOR MANUAL OR CALCULATOR CONTROL OF THE TRANSLATING MOVEMENTS, A SPEED CONTROL ROTARY SWITCH, A JOG IN/JOG OUT TOGGLE SWITCH AND RUN IN/RUN OUT TOGGLE SWITCH. THE LATTER THREE SHALL ONLY FUNCTION IN THE "MANUAL" POSITION. THE HEAD SHALL HAVE PROVISIONS FOR QUICK CONNECT AND DISCONNECT. ANY CABLES OR WIRES WHICH CONNECT WITH THE HEAD SHALL BE SUPPORTED BY A CABLE CARRIER FOR THE ENTIRE LENGTH OF TRAVEL AND SHALL PREVENT SAME FROM DRAGGING ON THE FLOOR. STATIONARY CABLES AND WIRES SHALL ALSO BE OFF THE FLOOR.

3.2.3.2 THE SYSTEM SHALL PROVIDE SUPPORT TO THE HEAD WHEN IT IS OUTSIDE THE BORE. A GUARD SHALL PROTECT THE HEAD FROM BEING DAMAGED BY THE TUBE. IF ANY OF THE HEADS WEIGH MORE THAN 35 POUNDS A LIFTING AND TRANSFER DEVICE SHALL BE PROVIDED TO MOVE THE HEADS FROM THE MOUNTED POSITION TO THE STORAGE POSITION. A SHELF OR RACK SHALL BE PROVIDED TO PROTECT AND STORE THE REQUIRED NUMBER OF HEADS PLUS ONE. THE HEAD SHALL HAVE A TAPERED NOSE PIECE TO ALLOW THE HEADS TO ENTER THE BORE FROM THE RETRACTED POSITION WITHOUT OPERATOR ASSISTANCE.

3.2.4 CALCULATOR/CONTROL SYSTEM.

3.2.4.1 THE CALCULATOR SHALL BE THE CONTROLLING ELEMENT FOR THE ENTIRE SYSTEM. WHEN THE INDEXING SYSTEM CONTROL SWITCH IS IN THE "AUTO" POSITION, THE SYSTEM, UNDER THE CONTROL OF THE CALCULATOR, SHALL START, STOP OR CHANGE DIRECTION AT ANY LOCATION ALONG THE BORE. TWO PUSHBUTTON CONTROLS SHALL ALSO BE PROVIDED; ONE LABELED "RUN" TO RELEASE THE CALCULATOR FROM A WAIT COMMAND AND ONE EMERGENCY STOP WHICH WILL DE-ENERGIZE THE SOLENOIDS TO THE DRIVE MOTORS. INTERLOCKS SHALL BE PROVIDED SO ROTATION OF THE TUBE CANNOT BE PERFORMED WHILE THE HEAD IS IN THE BORE.

3.2.4.2 THE CALCULATOR/PRINTER COMBINATION SHALL BE A HEWLETT PACKARD 9825A CALCULATOR, AN INTERFACED 9866B THERMAL LINE PRINTER AND A 98226A PRINTER CRADLE; (OR EQUAL). THE CALCULATOR/PRINTER WILL HAVE THE FOLLOWING MINIMUM FEATURES:

a. FULL ALPHANUMERIC KEYBOARD

b. 32 CHARACTER LED DISPLAY

c. BUILT-IN TAPE CARTRIDGE DRIVE

d. INTERRUPT CAPABILITIES

e. DIRECT MEMORY ACCESS

f. TRIGONOMETRIC CAPABILITIES

g. MINIMUM OF 15,000 BYTES OF READ/WRITE MEMORY

h. PRINT UPPER AND LOWER CASE ALPHANUMERIC TEXT ON 8½" WIDE PAPER AT 240 LINES/MIN MINIMUM.

THE CALCULATOR SHALL HAVE THE INTERFACES AND CABLES REQUIRED TO READ THE MEASUREMENT DISPLAYS, RESPOND TO THE "RUN" BUTTON AND CONTROL RELAYS OF THE INDEXING DRIVE SYSTEM.

3.2.5 CABINET ENCLOSURE. THE CABINET ENCLOSURE SHALL HOUSE THE LASER TRANSDUCER AMPLIFIER/DISPLAYS, THE HEAD INDEXING MEASURING AMPLIFER/DISPLAY, ALL REQUIRED POWER SUPPLIES AND ALL CABLES. ACCESS DOORS MUST BE PROVIDED FOR CALIBRATION AND SERVICE. THE FRONT DOOR MUST HAVE A CLEAR PLEXIGLASS WINDOW FOR EASY VISIBILITY OF ALL DISPLAYS. OPENINGS FOR REQUIRED CABLES SHALL BE PROVIDED. ALL SWITCHES, PLUGS, AND DISPLAYS SHALL BE LABELED WITH THEIR FUNCTIONS. THE CALCULATOR SHALL BE LOCATED ON A CABINET APPROXIMATELY 30 INCHES HIGH AND SHALL BE PROTECTED BY A CLEAR PLEXIGLASS COVER WHICH WILL ALLOW ACCESS TO THE CALCULATOR/PRINTER. DRAWERS SHALL BE PROVIDED FOR STORAGE OF PARTS AND SUPPLIES.

3.3 FUNCTIONAL CHARACTERISTICS. THE MACHINE SHALL BE CAPABLE OF:

3.3.1 ROTATING THE CANNON TUBES IN EITHER DIRECTION AT INFINITELY VARIABLE SPEEDS BETWEEN 0 AND 6 REV/MIN.

3.3.2 INDEXING THE HEADS THROUGH THE BORE AT INFINITELY VARIABLE SPEEDS BETWEEN 0 AND 4 INCHES/SEC IN BOTH DIRECTIONS. TOTAL TRAVEL SHALL NOT BE LESS THAN 28 FT.

3.3.3 THE POSITION MEASURING DEVICE FOR THE INDEXING SYSTEM SHALL MEASURE ACTUAL HEAD TRAVEL TO AN ACCURACY OF $\pm$ .015 INCHES. THE DISPLAY WILL BE A 6 DIGIT WITH A DECIMAL POINT, $\pm$ SIGN, AND INCH/METRIC CHOICE. LEAST SIGNIFICANT DIGIT FOR INCH WILL BE .01" AND .2 MILLIMETER FOR METRIC. CHARACTER HEIGHT .55" MINIMUM. DISPLAY WILL HAVE PRESETS AND RESET.

3.3.4 THE LASER ALIGNMENT SYSTEM SHALL HAVE THE FOLLOWING REQUIREMENTS:

a. RESOLUTION .005 INCHES

b. REPEATABILITY .01 INCHES

c. ACCURACY 3% OF MEASURED VALUE

d. RANGE, X AND Y, $\pm$ 1.50 INCHES

e. LASER OUTPUT POWER 1.0 MW ($\pm$ 0.5 MW)

f. LASER BEAM DIAMETER 1.4MM

g. LASER BEAM DIVERGENCE 0.8 MILLRADIAN

THE DIGITAL DISPLAYS SHALL BE 3½ DIGIT WITH DECIMAL POINT AND $\pm$ SIGN. RESOLUTION OF THE READOUT SHALL BE .005 INCH OR .1 MILLIMETERS FOR METRIC. CHARACTER HEIGHT .55" MINIMUM.

3.3.5 THE SYSTEM SHALL OPERATE IN A SHOP ENVIRONMENT WITH A TEMPERATURE RANGE OF 32°F TO 110°F AND RELATIVE HUMIDITY OF 20 TO 95%.

3.4 TECHNICAL DATA.

3.4.1 DATA SHALL BE FURNISHED AS FOLLOWS:
(2 COPIES EACH)

a. INSTALLATION DRAWINGS AND INSTRUCTIONS TO BE FURNISHED 60 DAYS PRIOR TO MACHINE DELIVERY.

b. WIRING DIAGRAMS TO BE FURNISHED 60 DAYS PRIOR TO MACHINE DELIVERY.

c. LUBRICATION INSTRUCTIONS TO BE FURNISHED WITH THE MACHINE.

d. OPERATOR INSTRUCTIONS TO BE FURNISHED WITH THE MACHINE.

e. PARTS LIST TO BE FURNISHED WITH THE MACHINE.

f. SERVICE MANUAL TO BE FURNISHED WITH THE MACHINE.

g. CONTRACTOR'S SUGGESTED SPARE PARTS LISTS TO BE FURNISHED WITH THE MACHINE.

h. CALIBRATION INSTRUCTIONS TO BE FURNISHED WITH THE MACHINE.

3.4.2 MACHINE AND CONTROL SYSTEM COMPONENTS WHICH ARE NOT MANUFACTURED BY THE CONTRACTOR AND WHICH ARE AVAILABLE FROM OTHER COMMERCIAL SOURCES, SHALL BE IDENTIFIED IN PARTS LISTS, FURNISHED WITH THE MACHINE, BY THE NAME OF THE ORIGINAL MANUFACTURER, DESCRIPTION OF COMPONENT, AND CATALOG MODEL OR PART NUMBER.

3.5 INSTALLATION/TRAINING

3.5.1 UPON RECEIPT OF MACHINE, WATERVLIET ARSENAL WILL RUN POWER TO MAIN CONTROL DISCONNECT SWITCH AND SET THE BASIC MACHINE (INCLUDING FOUNDATION IF REQUIRED) AND MAJOR COMPONENTS IN PLACE UNDER THE DIRECTION OF THE CONTRACTOR.

3.5.2 THE CONTRACTOR SHALL FURNISH A COMPETENT SERVICE ENGINEER TO PLACE THE MACHINE IN PROPER OPERATION, INSTRUCT OPERATORS IN THE PROPER OPERATION AND COMPLETE ORIENTATION IN THE GENERAL OVERALL APPLICATION OF THE MACHINE. THIS SERVICE ENGINEER SHALL BE PRESENT DURING THE FINAL ACCEPTANCE TEST AT WATERVLIET ARSENAL.

3.5.3 THE MANUFACTURER OF THE MACHINE DESCRIBED HEREIN SHALL PROVIDE, AS PART OF THE REQUIREMENTS OF THIS SPECIFICATION, OPERATOR AND MAINTENANCE TRAINING. THIS TRAINING SHALL CONSIST OF A MINIMUM OF 1 DAY OF QUALIFIED TECHNICAL INSTRUCTION AT THE WATERVLIET ARSENAL FOR:

2 MAINTENANCE PERSONNEL
2 OPERATORS

4. QUALITY ASSURANCE PROVISIONS.

4.1 PRELIMINARY INSPECTION AND TESTS.

THE SYSTEM SHALL BE EXAMINED FOR CONFORMANCE WITH PARAS 3.1 THRU 3.3.5. THE EXAMINATION AND TEST WILL BE PERFORMED PRIOR TO SHIPMENT TO WATERVLIET ARSENAL. FIVE (5) CERTIFIED COPIES OF THE EXAMINATION AND TEST RESULTS SHALL BE PROVIDED TO THE ARSENAL UPON COMPLETION OF THE TESTS. THE DATE OF TESTING SHALL BE FURNISHED AT LEAST TEN DAYS PRIOR TO TEST SO THAT IF THE CONTRACTING OFFICER DEEMS IT NECESSARY A GOVERNMENT REPRESENTATIVE MAY BE PRESENT TO WITNESS THE TESTS. THE TESTS AND EXAMINATIONS SHALL INCLUDE, BUT NOT BE LIMITED TO, THE FOLLOWING:

4.1.1 VISUAL INSPECTION OF SYSTEM FOR GENERAL COMPLIANCE.

4.1.2 USING A GOVERNMENT FURNISHED 105MM M68 CANNON TUBE FORGING (DWG NO F11579641) THE FOLLOWING PERFORMANCE TEST SHALL BE MADE:

a. ROTATING TUBE IN BOTH DIRECTIONS AND TESTING "JOG" AND "RUN" PROVISIONS AND VARIABLE SPEED DRIVE.

b. INDEXING MEASURING HEAD THROUGH THE BORE AND TESTING "RUN" AND "JOG" PROVISIONS, VARIABLE SPEED DRIVE, INCREMENTAL STOPPING ABILITY AND MEASURING ACCURACY.

c. USING A GOVERNMENT FURNISHED CALCULATOR PROGRAM, A TYPICAL INSPECTION RUN SHALL BE PERFORMED TO TEST THE MACHINE'S ABILITY TO FUNCTION AS DIRECTED BY THE CALCULATOR.

4.1.3 ALL ADJUSTING DEVICES WILL BE TESTED FOR FUNCTION.

4.1.4 THE STRAIGHTNESS MEASURING SYSTEM SHALL BE TESTED FOR ACCURACY OVER THE ENTIRE OPERATING RANGE USING GOVERNMENT APPROVED CALIBRATION EQUIPMENT.

4.2 FINAL ACCEPTANCE TEST.

AFTER INSTALLATION AT WATERVLIET ARSENAL, THE MACHINE SHALL BE SUBJECTED TO THE SAME EXAMINATIONS AND TESTS AS REQUIRED IN PARA 4.1 AND FOR COMPLIANCE WITH PARAS 3.4 AND 3.5. FAILURE OF THE MACHINE TO PASS ANY OF THE TESTS WILL BE CAUSE FOR REJECTION.

5. PREPARATION FOR DELIVERY.

5.1 PRESERVATION AND PACKAGING. PRESERVATION AND PACKAGING SHALL BE IN ACCORDANCE WITH STANDARD COMMERCIAL PRACTICE. ELECTRONIC EQUIPMENT SHALL BE PROTECTED WITH MOISTURE RESISTANT PACKAGING.

5.2 SKIDDING, BLOCKING AND BRACING, THE MACHINE SHALL BE ADEQUATLEY SKIDDED, BLOCKED AND BRACED TO PROVIDE AN EASY MEANS OF HANDLING AND LIFTING AND TO PROVIDE A SUITABLY RIGID FOUNDATION FOR THE EQUIPMENT. BLOCKING AND BRACING SHALL BE ACCOMPLISHED TO PREVENT MOVEMENT OF COMPONENTS OF THE MACHINE RELATIVE TO THEIR BASE, PREVENT MOVEMENT OF THE MACHINE RELATIVE TO ITS SKID, AND TO PREVENT MOVEMENT OF THE SKID RELATIVE TO THE CARRIER ON WHICH IT IS BEING TRANSPORTED. BLOCKING AND BRACING SHALL PREVENT MOVEMENT IN BOTH HORIZONTAL AND VERTRICAL PLANE. ELECTRONIC CONTROLS AND EQUIPMENT SHALL BE PACKED AND SHIPPED IN OR ON SHOCK RESISTING TYPE CARRIERS. IF SPECIAL LIFTING DEVICES, SUCH AS HOOKS OR EYE BOLTS, ARE REQUIRED FOR EASE OF HANDLING THEY SHALL BE SUPPLIED WITH THE MACHINE. THE ENTIRE SKID SHALL PROVIDE FOR MAXIMUM PROTECTION OF THE EQUIPMENT FOR SHIPMENT, HANDLING, LIFTING AND STORING.

5.3 MARKING. MARKING SHALL BE IN ACCORDANCE WITH MIL-STD-129.

6. INSTRUCTIONS AND OFFERORS.

6.1 BIDDER SHALL SUBMIT, IN TRIPLICATE, BROCHURES, CUTS, ILLUSTRATIONS, DRAWINGS OR A NARRATIVE DESCRIPTION WHICH CLEARLY INDICATES THAT THE DESIGN, CONSTRUCTION AND OPERATING FEATURES OF THE MACHINE AND RELATED ACCESSORIES OFFERED WILL MEET ALL OF THE REQUIREMENTS. THE LITERATURE SUBMITTED MUST INDICATE THE OVERALL SIZE AND CONFIGURATION OF THE MACHINE AND RELATED COMPONENT PARTS, SUCH AS BED, ROLLERS, DIGITAL READOUT DISPLAY, AND ELECTRONIC SYSTEM ASSURING THAT THE RANGES AND CAPACITIES WILL BE MET BY THE MACHINE BEING OFFERED. THIS DATA IS REQUIRED FOR EVALUATION OF EQUIPMENT OFFERED AND PROPOSALS SUBMITTED WITHOUT IT WILL BE REJECTED.

6.2 LITERATURE COVERING MORE THAN ONE MODEL OR SIZE MUST BE CLEARLY MARKED TO INDICATE THE EXACT MODEL AND SIZE BEING PROPOSED.

6.3 IN ADDITION TO THE FOREGOING, OFFERORS MUST INDICATE, ON A PARAGRAPH BY PARAGRAPH BASIS, WHETHER OR NOT THEY COMPLY WITH EACH PARAGRAPH OF THIS SPECIFICATION. OFFERORS DEVIATING IN ANY RESPECT FROM A SPECIFIC PARAGRAPH(S) MUST DESCRIBE IN DETAIL HOW THEY PROPOSE TO COMPLY WITH THE PARTICULAR REQUIREMENT(S) THEREIN. FOR EXAMPLE:

Appendix B

SOLICITED FIRMS

1. Applied Optomechanical Kinetics, Stow, MA
2. Marposs Gauges Corp., Madison Heights, MI
3. Bendix Corp., Automation & Measurement Division, Dayton, OH
4. Diffracto Ltd., Windsor, Ontario
5. Hamar Laser Instruments Inc., Wilton, CT
6. Coherent Laser Division, Palo Alto, CA
7. Raytheon, Industrial Laser System, Burlington, MA
8. Maxwell Laboratories Inc., San Deigo, CA
9. Laser Precision Corp., Utica, NY
10. Jodon Engineering Associates Inc., Ann Arbor, MI
11. Reluxtrol Inc., South San Francisco, CA
12. Foerster Instruments Inc., Coraopolis, PA
13. Ellis Engineering Inc., Danvers, MA
14. Sigma Dynamics Corp., Willow Grove, PA
15. Computer Tech Corp., Milford, OH

TECHNICAL REPORT INTERNAL DISTRIBUTION LIST

	NO. OF COPIES
COMMANDER	1
TECHNICAL LIBRARY ATTN: DRDAR-LCB-TL	5
DIRECTOR, OPERATIONS DIRECTORATE	2
DIRECTOR, PRODUCT ASSURANCE DIRECTORATE	1
ASSOCIATE DIRECTOR, BENET WEAPONS LABORATORY	2

NOTE: PLEASE NOTIFY COMMANDER, WATERVLIET ARSENAL, ATTN: SARWV-QAE, WATERVLIET, NY 12189, OF ANY REQUIRED CHANGES.

TECHNICAL REPORT EXTERNAL DISTRIBUTION LIST

	NO. OF COPIES
ASST SEC OF THE ARMY RESEARCH & DEVELOPMENT ATTN: DEP FOR SCI & TECH THE PENTAGON WASHINGTON, D.C. 20315	1
COMMANDER US ARMY MAT DEV & READ COMD ATTN: DRCDE 5001 EISENHOWER AVE ALEXANDRIZ, VA 22333	1
COMMANDER US ARMY ARRADCOM ATTN: DRDAR-LC -TSS (STINFO) DOVER, NJ 07801	1 2
COMMANDER US ARMY ARRCOM ATTN: DRSAR-QA -IR -LEP-L ROCK ISLAND ARSENAL ROCK ISLAND, IL 61299	1 1 1
DIRECTOR US ARMY BALLISTIC RESEARCH LAB ATTN: DRDAR-TSB-S (STINFO) ABERDEEN PROVING GROUND, MD 21005	1
COMMANDER US ARMY ELECTRONICS COMD ATTN: TECH LIB FT MONMOUTH, NJ 07703	1
COMMANDER US ARMY MOBILITY EQUIP R&D COMD ATTN: TECH LIB FT BELVOIR, VA 22060	1
COMMANDER US ARMY TANK-AUTMV R&D COMD ATTN: TECH LIB-DRDTA-UL WARREN, MICHIGAN 48090	1
COMMANDER US MILITARY ACADEMY ATTN: CHMN, MECH ENGRG DEPT WEST POINT, NY 10996	1
US ARMY MISSILE COMD REDSTONE SCIENTIFIC INFO CEN ATTN: DOCUMENTS SECT, BLG 4484 REDSTONE ARSENAL, AL 35898	2
COMMANDER US ARMY FGN SCIENCE & TECH CEN ATTN: DRXST-SD 220 7TH STREET, N.E. CHARLOTTESVILLE, VA 22901	1
COMMANDER US ARMY MATERIALS & MECHANICS RESEARCH CENTER ATTN: DRXMR-PL -D -FI -S -M -AT WATERTOWN, MA 02172	2 1 1 2 1

NOTE: PLEASE NOTIFY COMMANDER, WATERVLIET ARSENAL, ATTN: SARWV-OAE, WATERVLIET, NY 12189, OF ANY REQUIRED CHANGES.

TECHNICAL REPORT EXTERNAL DISTRIBUTION LIST (CONT.)

	NO. OF COPIES
COMMANDER US ARMY RESEARCH OFFICE P.O. BOX 12211 RESEARCH TRIANGLE PARK, NC 27709	1
COMMANDER US ARMY HARRY DIAMOND LAB ATTN: TECH LIB 2800 POWDER MILL ROAD ADELPHIA, MD 20783	
DIRECTOR US ARMY INDUSTRIAL BASE ENG ACT ATTN: DRXPE-MT ROCK ISLAND, IL	1
COMMANDER NAVAL SURFACE WEAPONS CEN DAHLGREN, VA 22448	1
DIRECTOR US NAVAL RESEARCH LAB ATTN: DIR, MECH DIV CODE 26-27 (DOC LIB) WASHINGTON, D.C. 20375	1 1
NASA SCIENTIFIC & TECH INFO FAC P.O. BOX 8757, ATTN: ACQ BR BALTIMORE/WASHINGTON INTL AIRPORT MARYLAND 21240	1

	NO. OF COPIES
COMMANDER DEFENSE TECHNICAL INFO CENTER ATTN: DTIC-TIR -LTD CAMERON STATION ALEXANDRIA, VA 22314	10 2
DIRECTOR BATTELLE COLUMBUS LAB 505 KING AVE COLUMBUS, OHIO 43201	1

NOTE: PLEASE NOTIFY COMMANDER, WATERVLIET ARSENAL, ATTN: SARWV-QAE, WATERVLIET, NY 12189, OF ANY REQUIRED CHANGES